Metal Matrix Composites for Rocket Engine Applications

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Rocketdyne
Propulsion & Power

- Need for Advanced Materials
- Components and Weights
- Materials Selection Criteria
- Metal Matrix Composites
- Technical Issues
- Conclusions and Recommendations

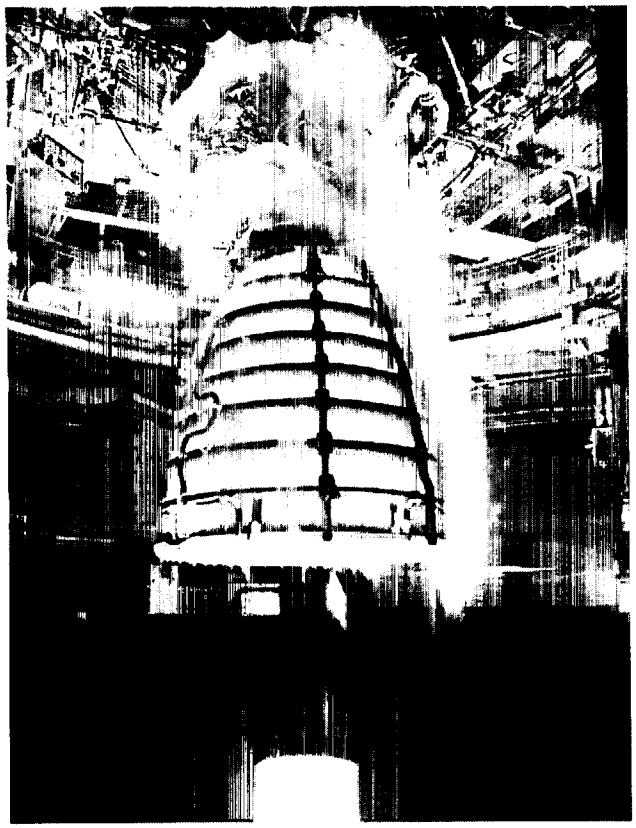
- AF Integrated High-Payoff Rocket Propulsion (IHPRPT) Goals for Year 2010 for "Boost and Orbit Transfer" Propulsion

  Double Thrust to Weight

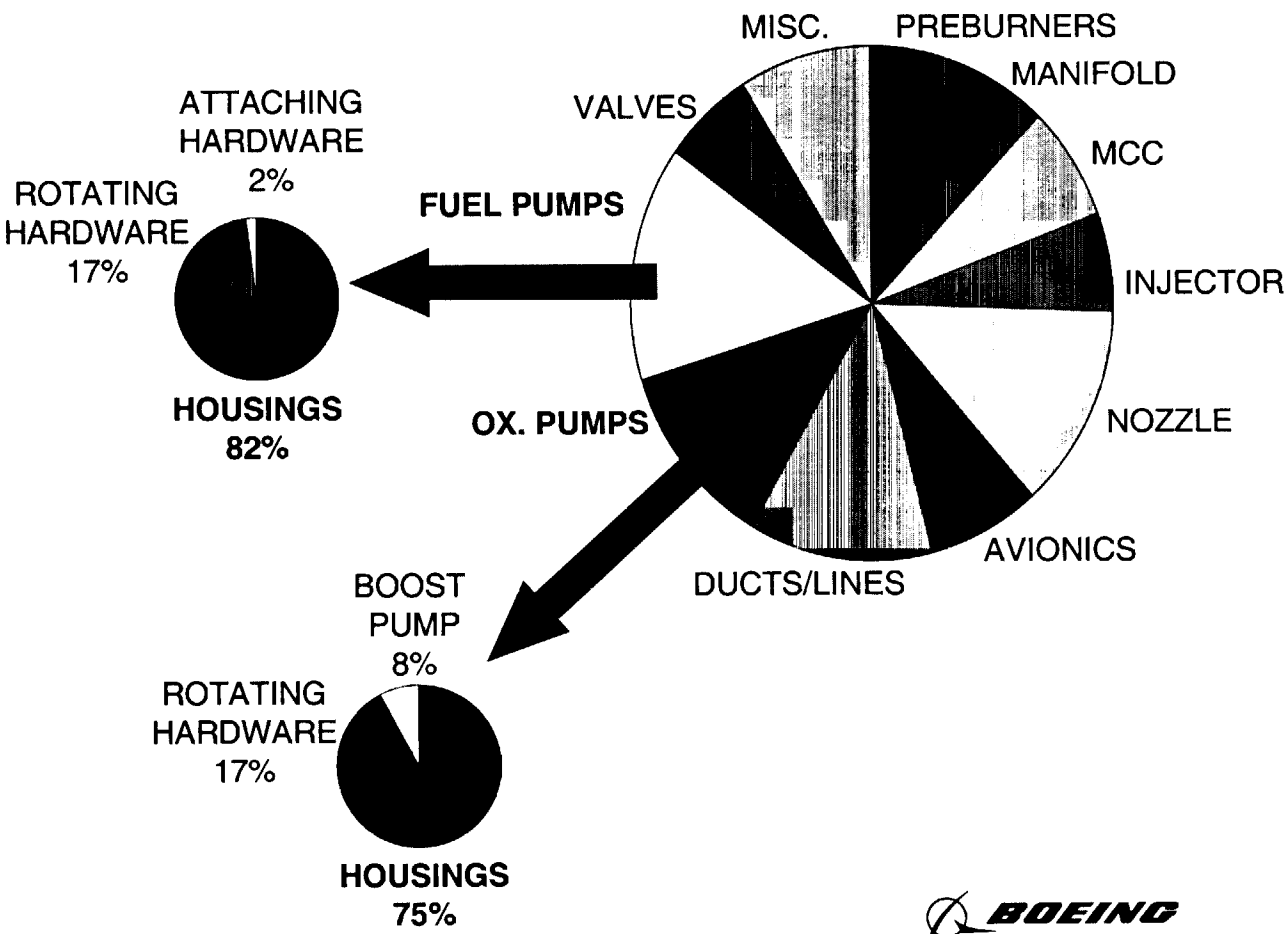
  Reduce Hardware Costs by 35%

- NASA Goal 9 Low-Cost Space Access

  "Reduce the payload cost to low-Earth orbit by an order of magnitude, from $10,000 to $1,000 per pound within 10 years, and.."



SSME Engine Weight Distribution (7037 lbs)



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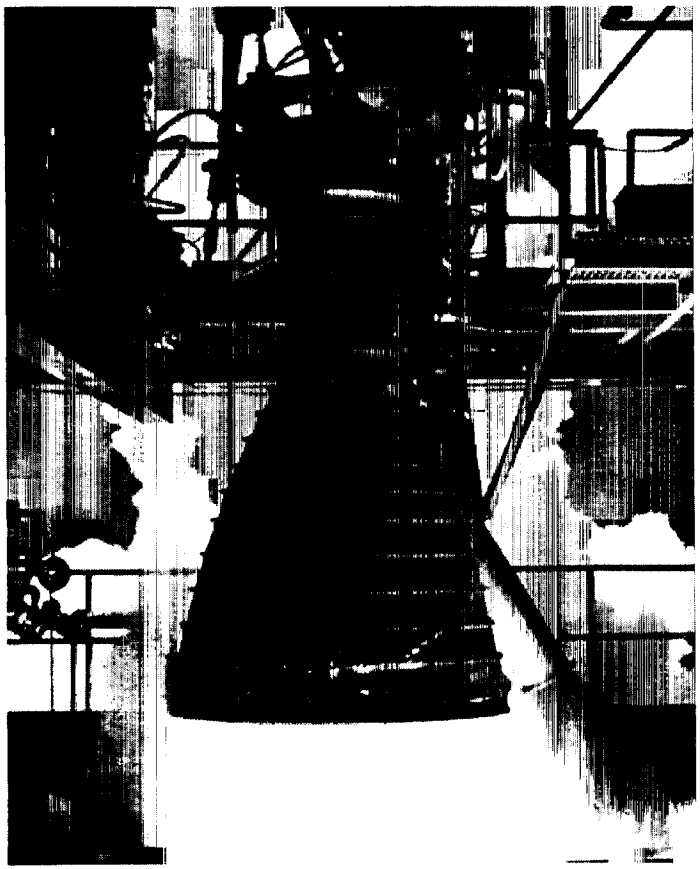
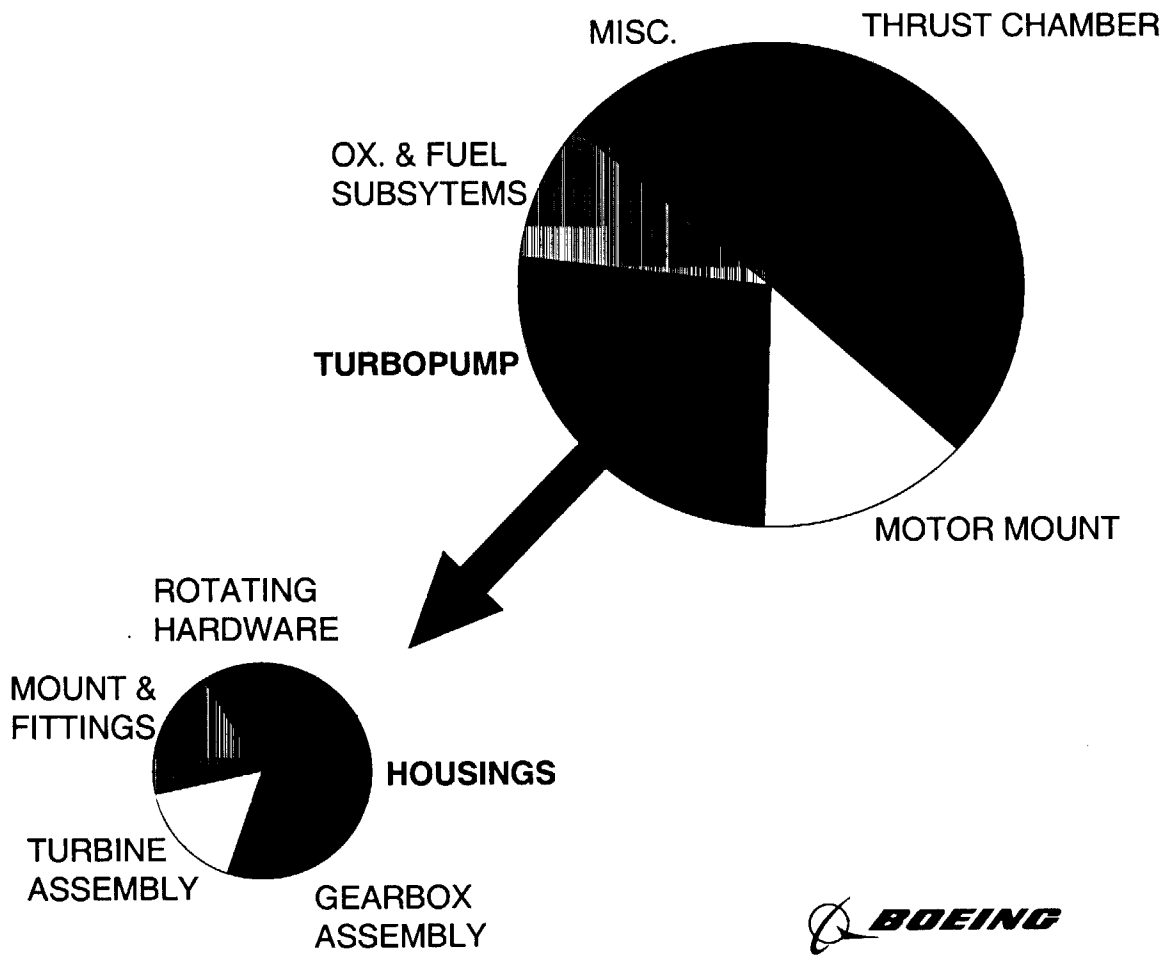


RS27 Weight Distribution (2571 lbs)



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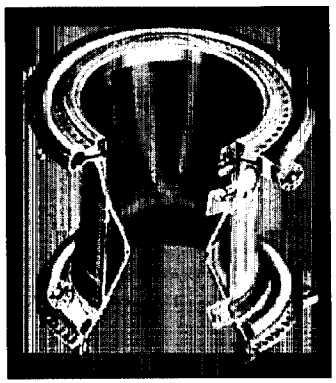
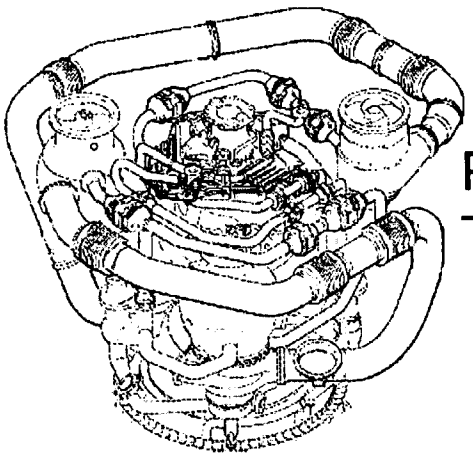
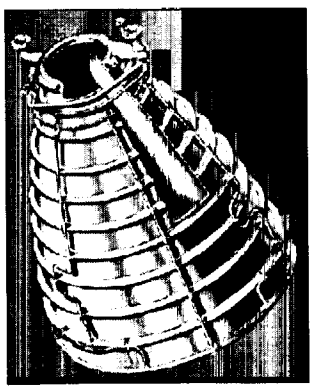
- Properties Over Operating Temperature Range
  - High Specific Strength
  - Compatibility
    - Fuel
    - Oxidizer
    - Combustion Products
- Affordable and Producible



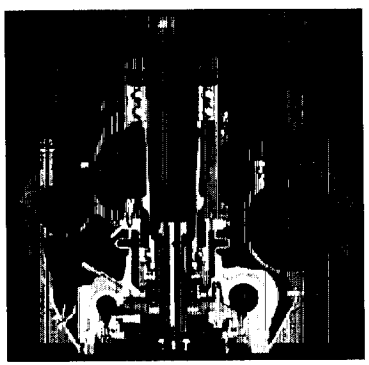
Inlet pressure 5647 psia
Exit pressure 4441 psia
Coolant inlet -366°F
Max wall temp 1000°F



Pressure 425 psia
Temperature 420°F

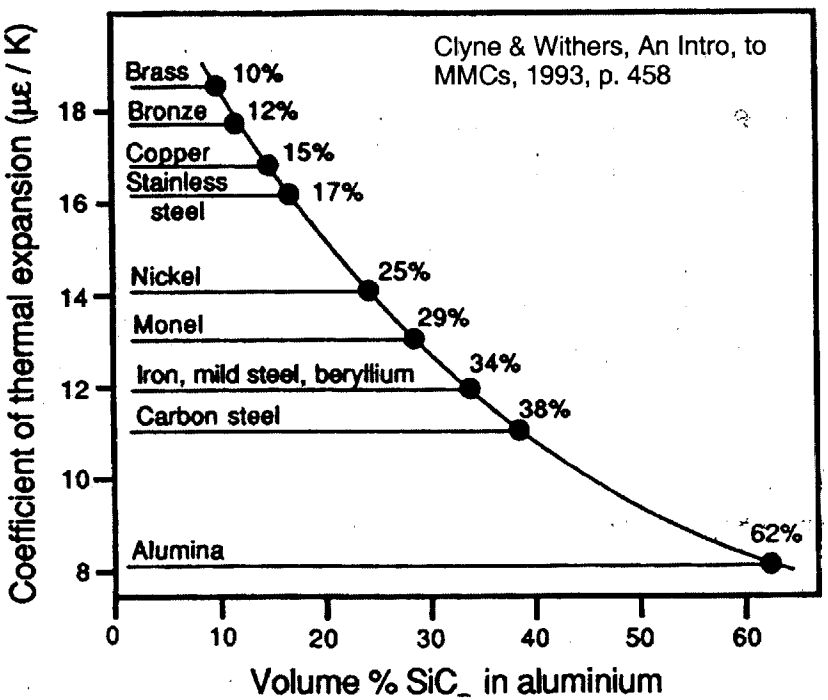


Inlet pressure 5624 psia
Exit pressure 5420 psia
Max wall temp 950°F



Inlet Pressure 422 psia
Inlet Temp -272°F
Exit Pressure 4300 psia
Turbine Speed 28120 rpm

• Tailored Properties



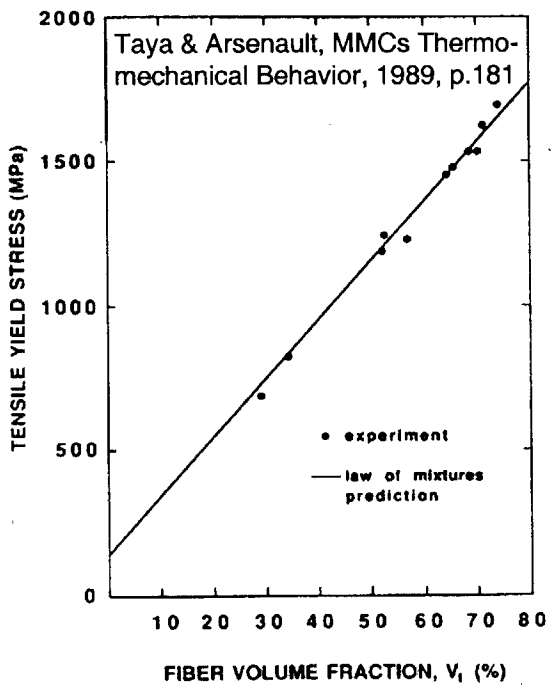
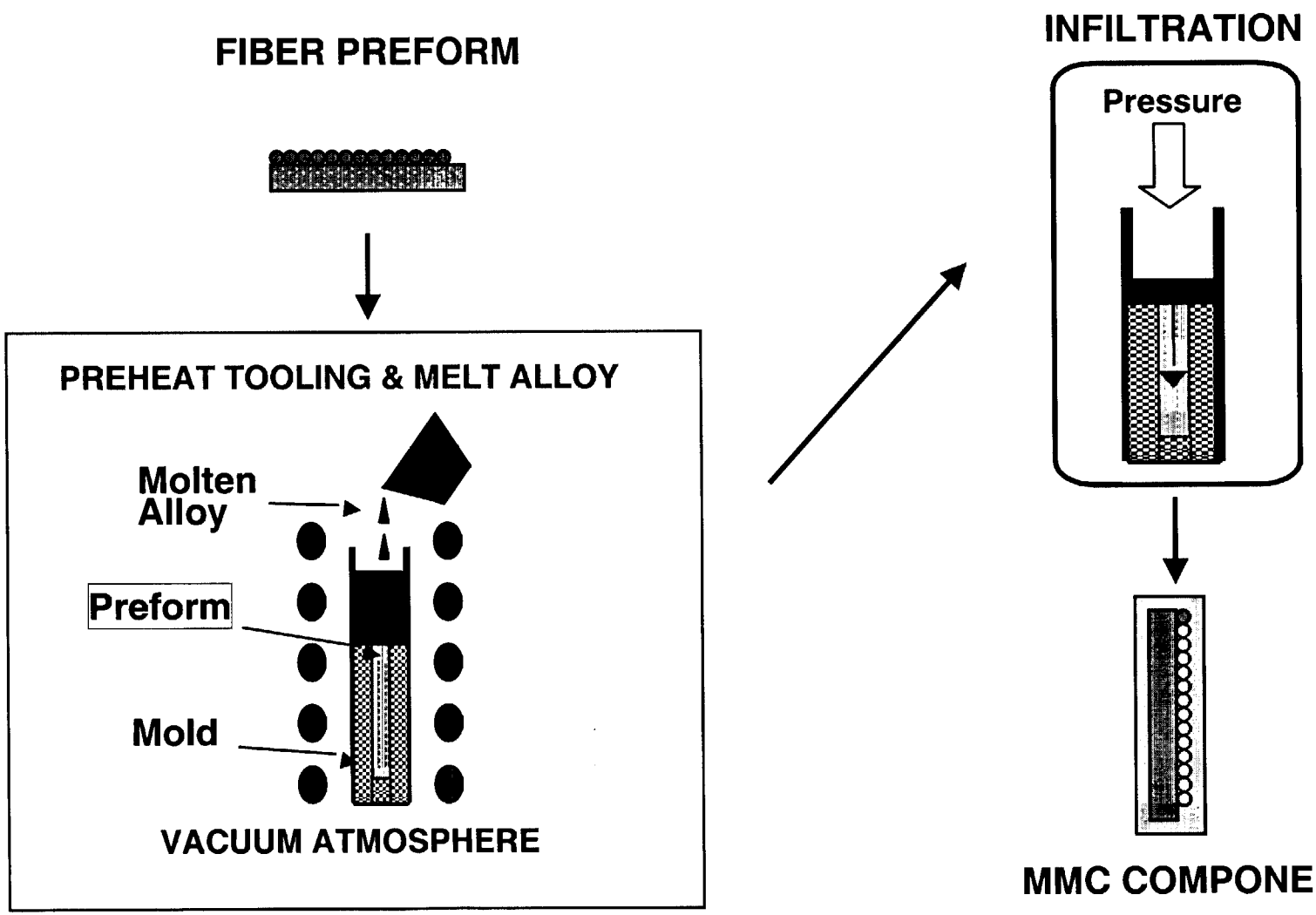


FIG. 3.9 Tensile yield stress of a continuous tungsten fiber/copper composite as a function of fiber volume fraction, V_f (%).


FIBER PREFORM
PREHEAT TOOLING & MELT ALLOY
Molten Alloy
Preform
Mold
VACUUM ATMOSPHERE
INFILTRATION
Pressure
MMC COMPONENT

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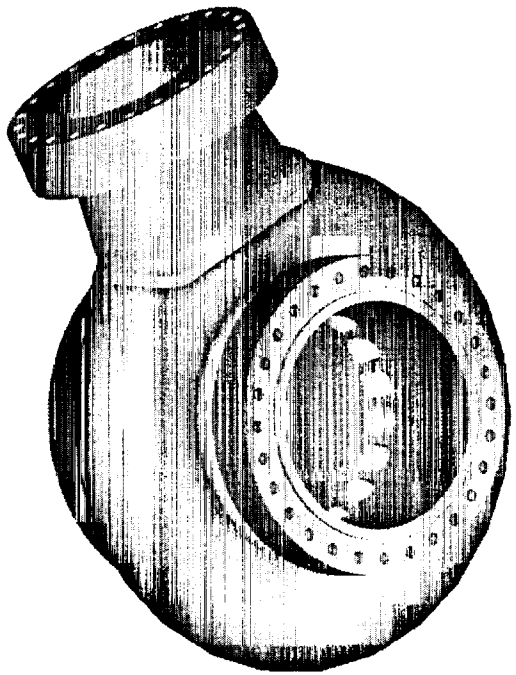
- Property Data Not Complete For Many MMC Systems
- Matrix/Reinforcement Interactions Must Be Understood and Controlled
- Manufacture of Large Complex Parts Difficult

Selected Component: Reusable Turbopump Housing

Requirements:

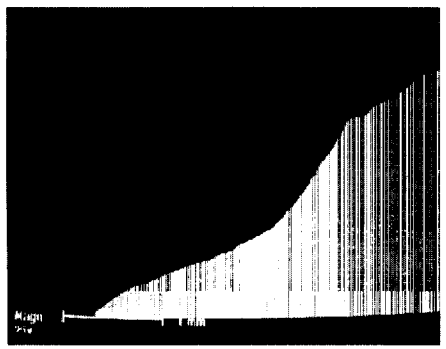
- High Specific Strength, Stiffness
- Oxygen Compatibility
- Contain High Pressure
- Good Toughness
- Fatigue Resistant
- Producible, Affordable



Solutions		Issues
Use High Strength Alloys with Coatings	→	Maintainability Reliability
Use Low Strength, Compatible Alloys	→	Weight Penalty
Develop High Strength, Compatible Materials	→	Development Producibility Joining

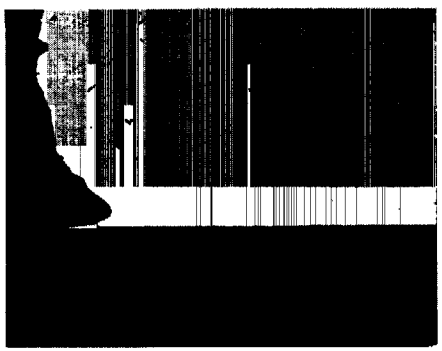
Alloy Selection

- Cu Base for Burn Resistance
- Alloying Elements
  - Al for Oxidation Resistance
  - Zn, Ge, or Mn for Melting Temperature Reduction
  - Ti, Si, or Cr for Wetting and Bonding

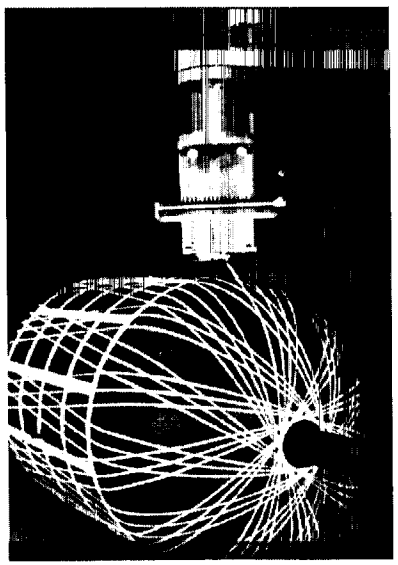


Fiber/Matrix Interaction Studies

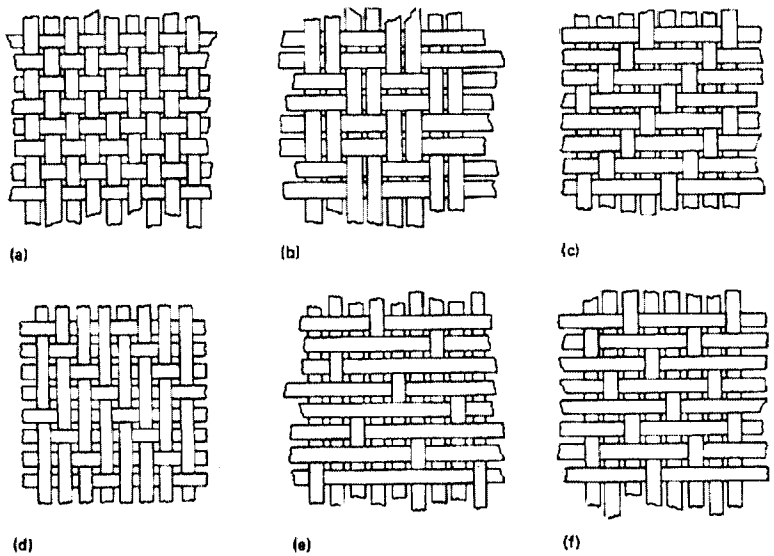
- Bonding and Wetting
- Grain Size Refinement



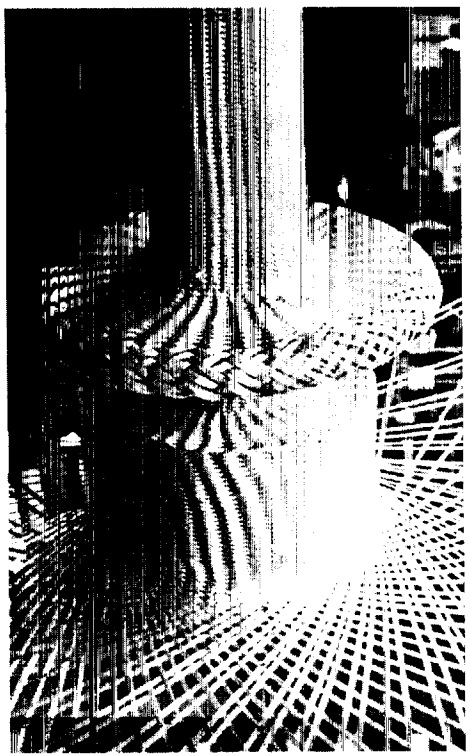
- Define and Manufacture Subelements
- Integrate Preforms for Single Infiltration



Advanced Composites Inc., 2000



Engineering Materials Handbook Vol.1:Composites,
ASM International, 1987, pp. 148, 522



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- Demonstrate Propellant Compatibility
- Design to Optimize Fiber Orientation and Anisotropy
- Develop Preform Manufacturing Technology
- Minimize Processing Damage to Fibers
- Establish Mechanical Properties Database
- Demonstrate Attachment Schemes
- Validate Processing Techniques and Producibility
- Verify Inspection Methods

- Industry Goals Call for Engine Weight Reduction
- MMCs Offer Several Potential Benefits
  - High Specific Strength
  - Tailored Properties
  - Producibility
- Turbopump Housings Targeted for MMC Development
- Several Technical Challenges Remain
- MMC Technology Development Provides Potential for Weight Savings in Other Engine Components